

Standard Operating Procedures for Creating Contours from High-Resolution Digital Terrain Models (DTM) with ArcMap 10.3

USGS Astrogeology Science Center

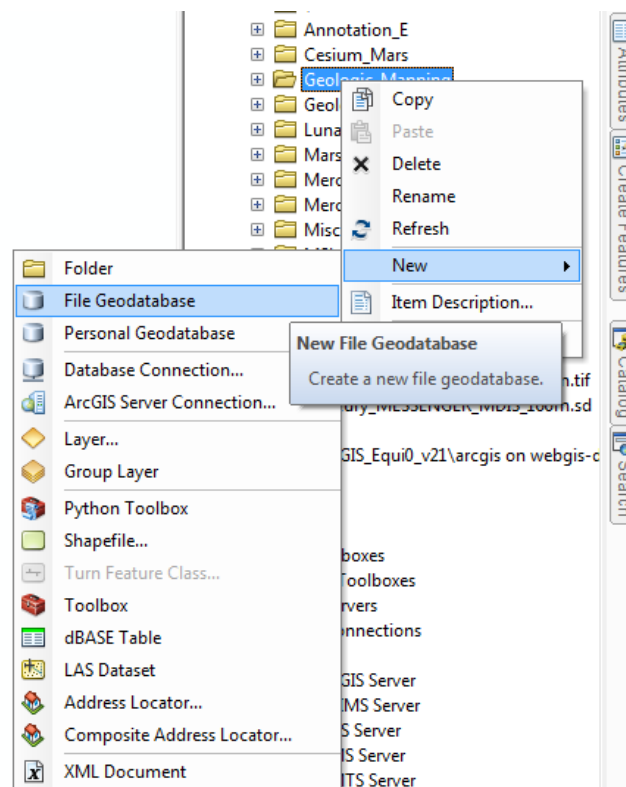
MRCTR GIS Lab

Flagstaff, AZ

Last Revised: 09/07/2018

This SOP is meant to serve as a common workflow to create consistent, easy to read contours for use in planetary geologic maps. However, ArcGIS provides many different tools to perform similar tasks and others not illustrated here may be more appropriate based on the users DTM and desired map aesthetic. One step of this SOP utilizes a geoprocessing tool (Contour Annotation) introduced in ArcGIS 10.3, so if authors are working with an older version there is a workaround addressed, but not detailed, in this document.

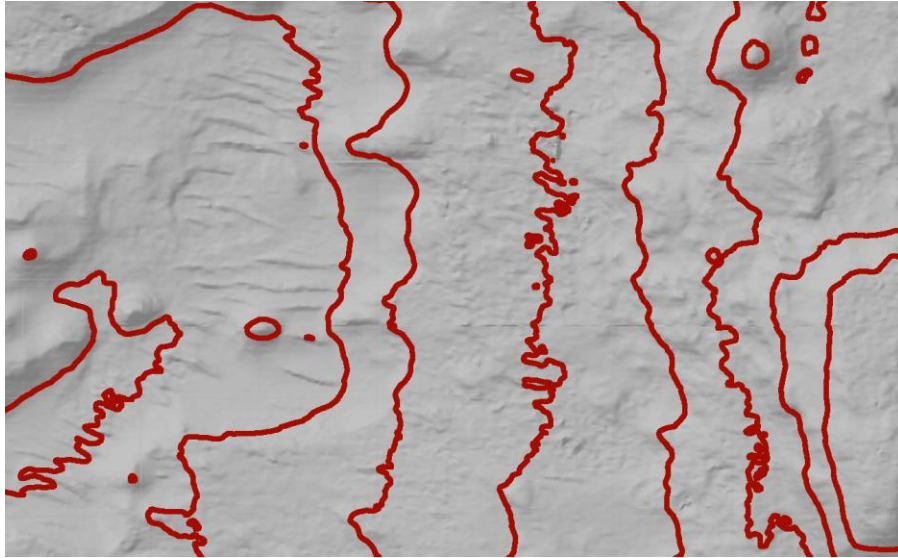
1) Create a file geodatabase (*.gdb) and use this as scratch and current workspaces in the Environments settings, under the Geoprocessing tab. Geodatabases are required to generate feature annotation, and has the added benefit of automatically providing feature lengths.



Create a file geodatabase through Arc Catalog or the Catalog tab in a map document.

Note: Define the reference scale of the map document prior to setting symbology for any layers by navigating to the General tab of the Data Frame Properties window.

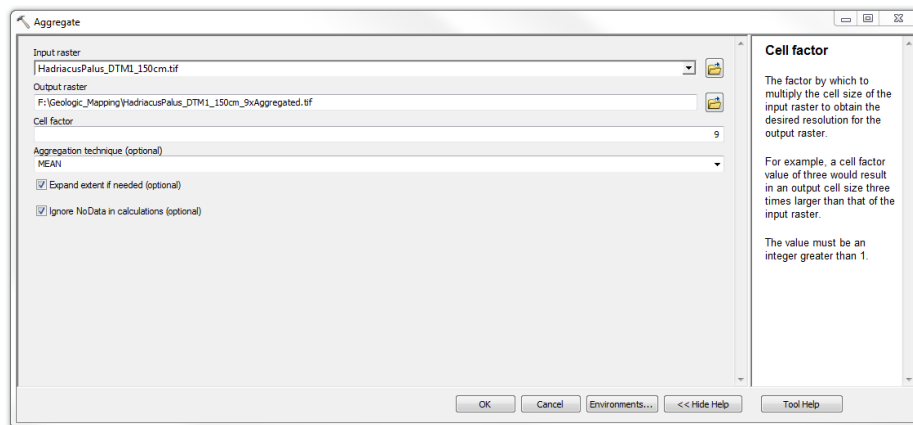
2) Assess the DTM. High-resolution images, such as HiRISE, yield contours that are exceedingly detailed which detract from the readability of the map and must be down-sampled.



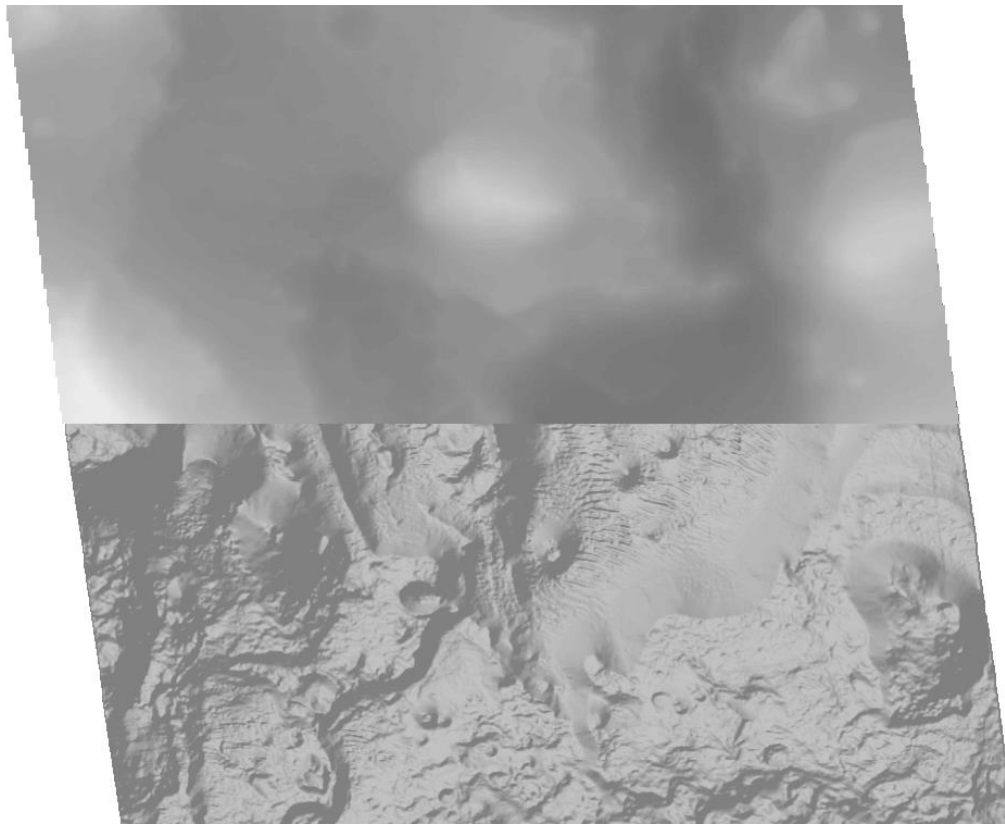
Rough contours and outliers created from using the original, 1.5 meter-resolution DTM.

3) Use the **Aggregate** tool to reduce the image resolution using the mean aggregation technique. The recommended initial value is 9 for very high resolution imagery.

Note: In addition to the Aggregate tool users may also generalize DTMs with a low-pass filter or bilinear resampling. In this example the contours derived from the Aggregate tool were smoother than others.

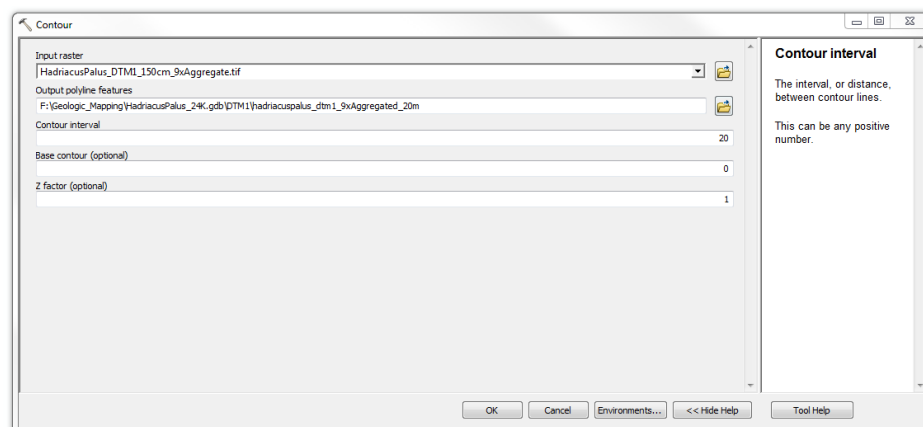


Example settings for the Aggregate tool.



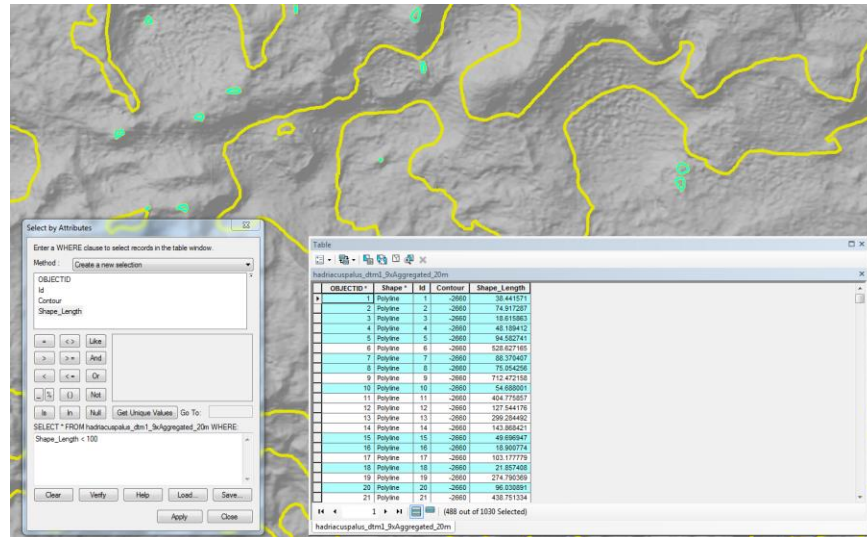
The generalized Aggregate output DTM (top) compared to the original resolution (bottom).

- 4) Generate contours with the **Contour** tool, ensuring the output polyline feature is saved to the geodatabase.



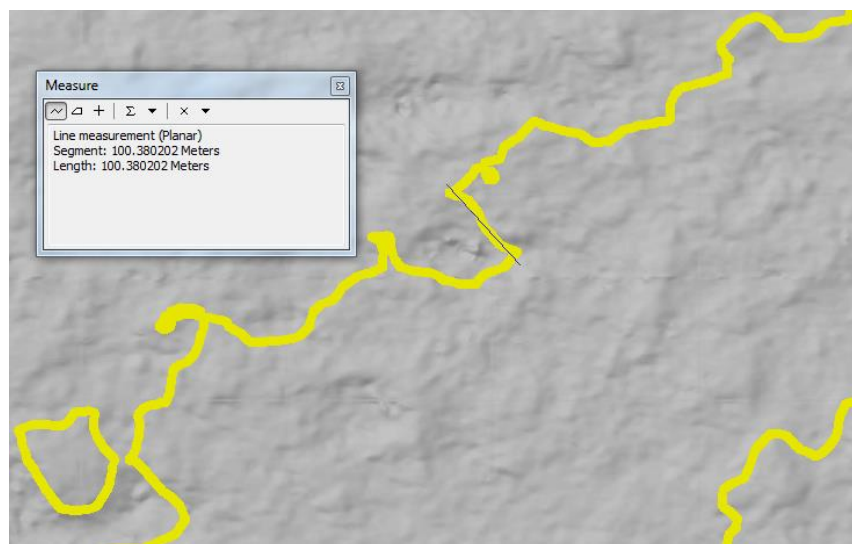
Example settings for the Contour tool.

5) Outlier contours will be generated; select some of the largest outliers you wish to delete and record the maximum length. Use this to determine the maximum outlier size, use Select by Attribute with a SQL query (i.e., Shape_Length < 100), and then delete the selected features. Or, as a starting point multiply the generalized DTM resolution by 20. Then review the map and delete any individual outliers that are poor indicators of topography (these are often found on near-horizontal terrain, dune fields and buried crater rims).

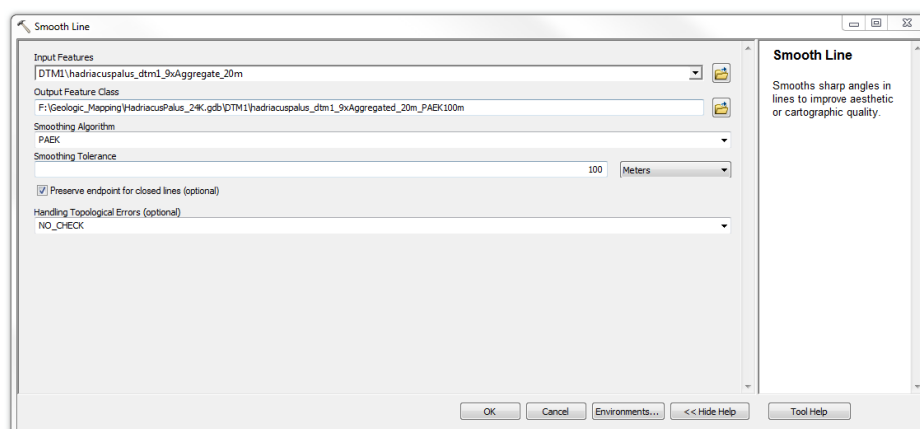


Select outliers with Select by Attribute. Individual outliers may be deleted separately.

6) Identify a contour that you wish to be smoothed, and measure its widest variance - this will be the initial smoothing tolerance. With the **Smooth Line** tool, select the PAEK smoothing algorithm and set the smoothing tolerance (if in doubt use a generous estimate). Check this output for desired smoothness and run again if necessary.



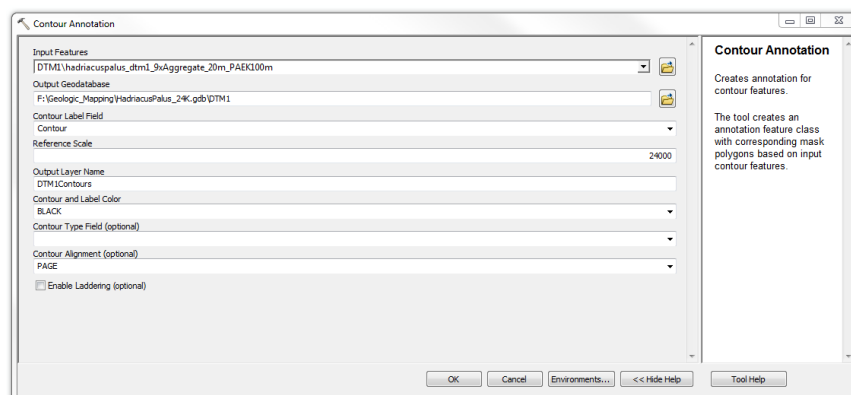
Measuring the maximum roughness of contours to use in the smoothing tool.



Example settings for the Smooth Line tool.

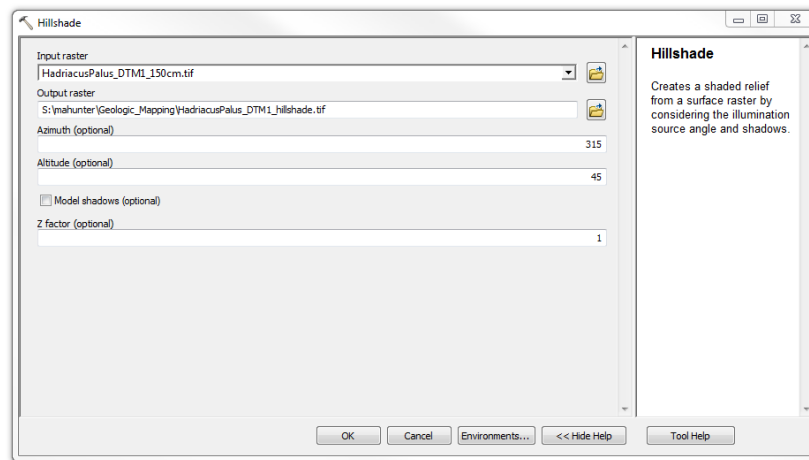
7) Then run the **Contour Annotation** tool, using the map scale as the reference scale and verify that the contour label field is set to CONTOUR. The Enable Laddering option stacks contour labels throughout the map. This will generate a layer with three feature classes that can be edited separately (contour features, annotation and a mask which can be turned off). Now all required datasets are ready to create the map.

Note: This tool does not allow for customized label placement other than laddering (stacking) labels and orientation. If authors wish to define custom label placement rules via the Maplex labeling engine then labels must be converted to annotation, and masks created for the annotation. Some customization to reduce clutter in the map can be performed through simple SQL statements, see Step 11 for details.



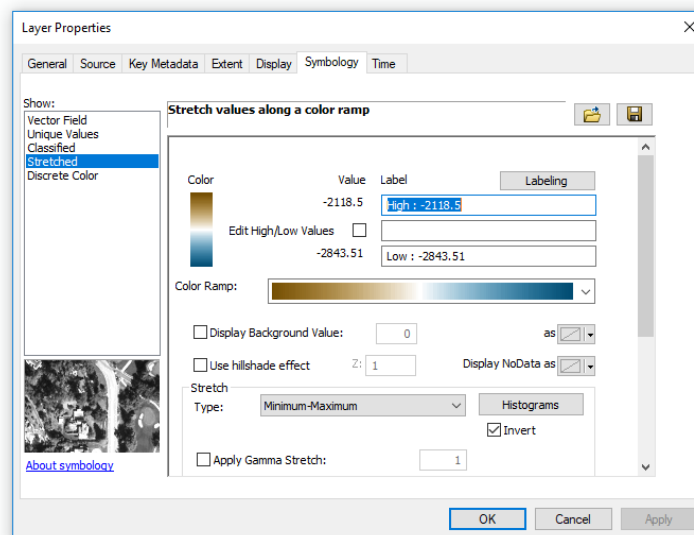
Example settings for the Contour Annotation tool.

8) Authors may use the original resolution DTM with hillshade enabled as the base; however, it is recommended that the **Hillshade** tool is used to create a new raster. On-the-fly hillshade creates less precise, and more occluded, topography relief.



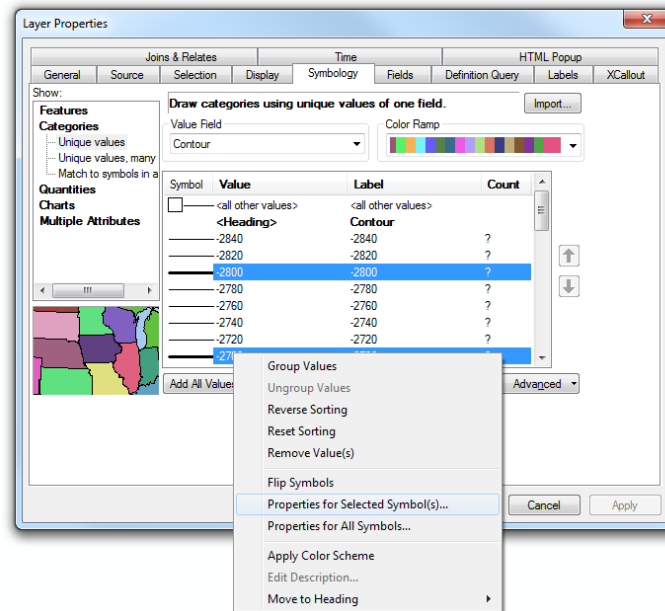
Example settings for the Hillshade tool.

9) Next, add the down-sampled DTM with 60% transparency and the Precipitation color ramp (inverted) stretched by 1.5 standard deviations.

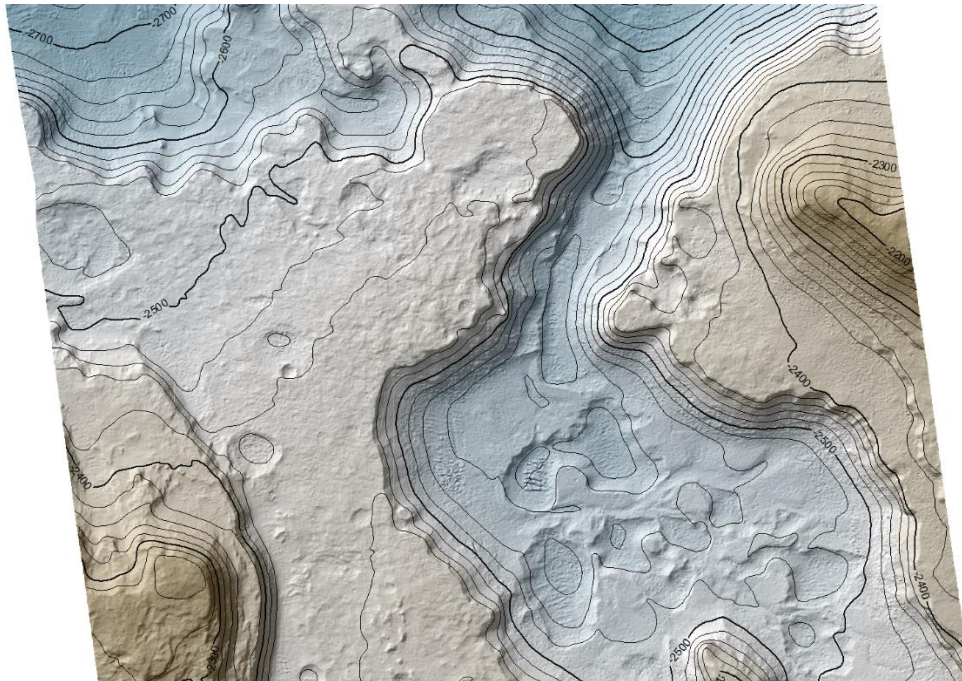


Setting symbology properties for the generalized DTM.

10) Lastly, add the contour and annotation features, and then import the symbology for the IndexedContours layer file (*.lyr). If that layer file is not available set the symbology to Unique Values > Contour field, set all lines to 0.15 millimeter solid black lines, then CTRL+select the index values and change them to 0.25 millimeter lines.



Selecting index contours and setting symbology properties.



Example of the final product created through this workflow.

Note: When exporting the final map to an Adobe Illustrator file (*.ai) or PDF (*.pdf) ensure vectors graphics are not compressed and that picture symbols are set to “Vectorize layers with bitmap markers/fills”. This creates a much larger file, but ensures lines remain smooth. Also, if the map/figure is to be sent to USGS Publications be prepared to provide the unbroken contours as well so that labels can be modified.

CUSTOMIZATION

11) If a cleaner base map is preferred, then a set of basic SQL queries may be used to display only the index contours with annotation, and intermediary contours with no labels. To do so add the original smoothed contours layer back into the map document and restrict it to non-index contours with the following definition query:

Floor(Contour/100) <> Contour/100

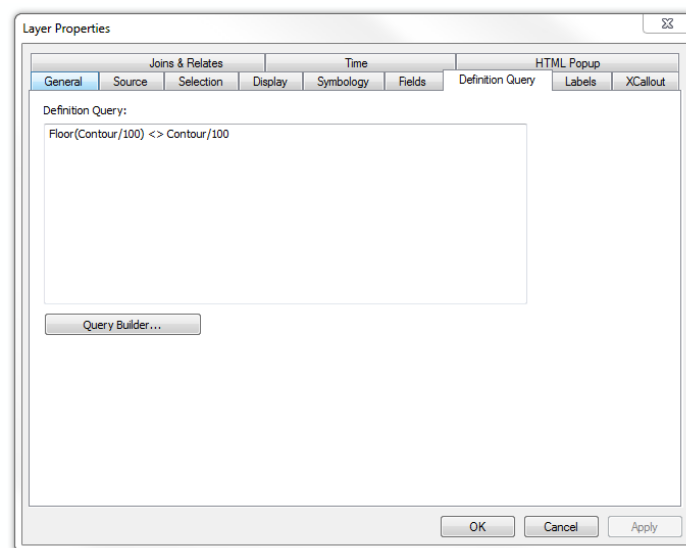
Then apply this query to the index contours:

Floor(Contour/100) = Contour/100


Finally, apply this query to the index contour annotation class:

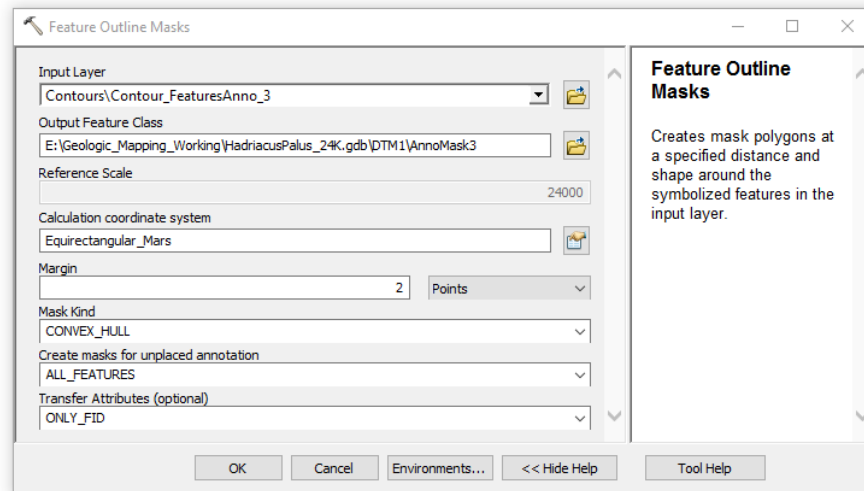
TextString LIKE '%00'

These SQL queries are based on indexes every 100 meters and may have to be modified if contour intervals are different.



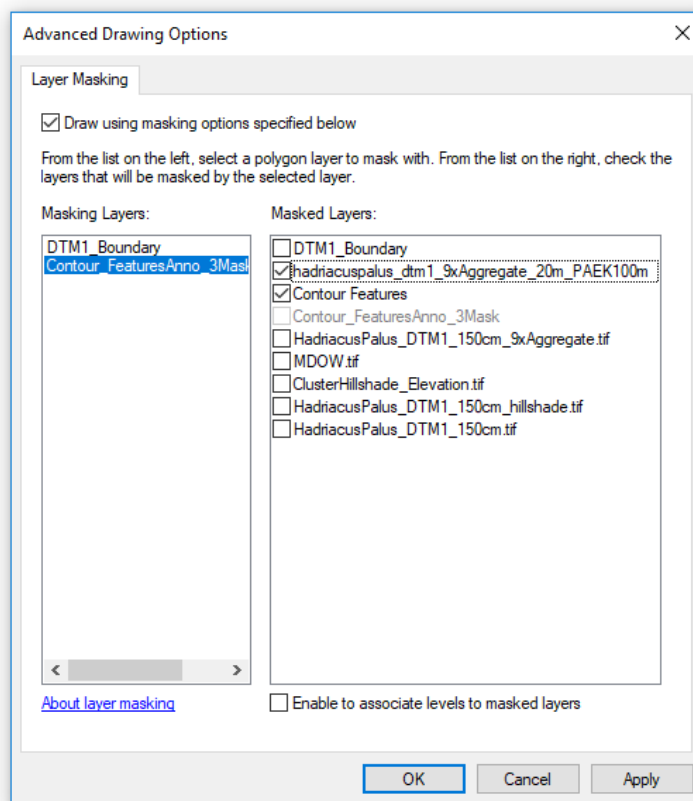
Example definition query using a SQL query.

12) The default index contour label placement may not be ideal; crossing unit contacts, labels or other map elements. In this case the author can move, rotate and otherwise modify annotation in edit mode, like any other vector object. Note, that when editing annotation, it is important to use the Edit Annotation Tool . Once contour annotation labels are placed new masks can be made using the **Feature Outline Masks** tool. Ensure that the reference scale and coordinate system match the map, and to use a margin of at least 2 points, and 'convex hull' mask type.

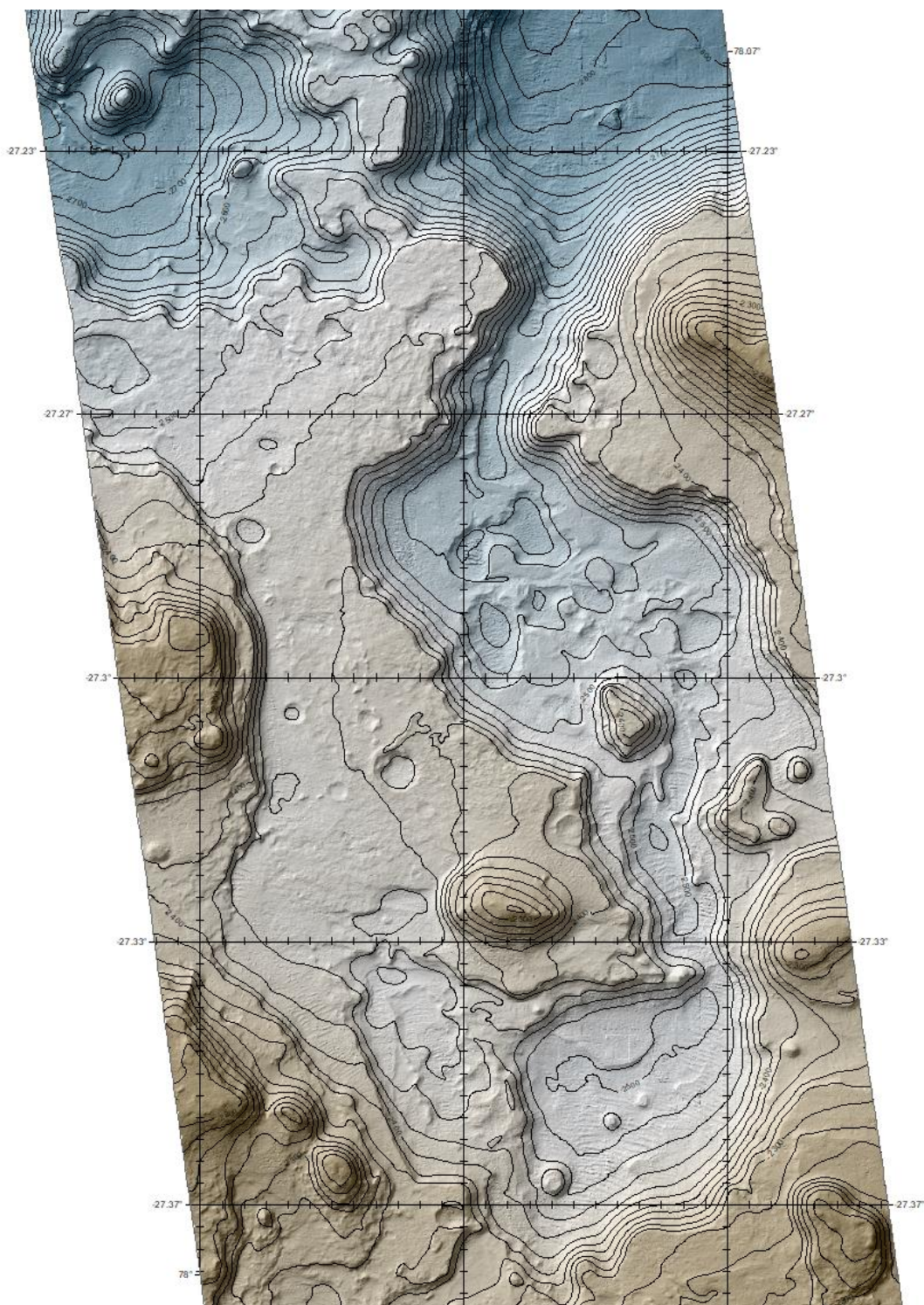


Example settings for the Feature Outline Masks tool.

13) The layer file generated by the Contour Annotation tool automatically enforces variable depth masking, which allows the annotation mask to operate only on the contour layers, but this does not happen automatically when copying the data to a new map document. To correct this, navigate to Advanced Drawing Options by right-clicking on the data frame. Check the box "Draw using masking options specified below", and select which layers are to be the mask and which layers they are to be applied.



A useful Esri blog post walking through variable depth masks can be found [here](#).



Example final product with graticule overlay.

Please direct any questions, comments or improvements to:

Marc Hunter

USGS Astrogeology Science Center

Flagstaff, AZ

mahunter@usgs.gov